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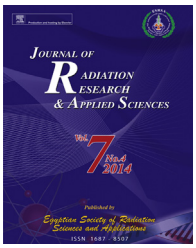

Distribution of natural radionuclide along Main Central Thrust in Garhwal Himalaya

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ABSTRACT

Study of natural radionuclide is important to assess the radiation level in a particular area. Radionuclide present in earth's crust is different for different geological areas because of the variety of soil and rocks present in a particular area. In present study, the estimation of natural radionuclides have been carried out along the Main Central Thrust (MCT) in Uttarkashi, Budhakedar, Ukhimath and Healang regions of Garhwal Himalaya, India. The large variations in the radionuclide distribution have been estimated along the Main Central Thrust. The ^{226}Ra, ^{232}Th and ^{40}K contents in MCT area varies from 8 ± 1 Bq.kg^{-1} to 285 ± 28 Bq.kg^{-1} with an average of 64 Bq.kg^{-1}, 7 ± 1 Bq.kg^{-1} to 136 ± 15 Bq.kg^{-1} with an average 69 Bq.kg^{-1} and 115 ± 18 Bq.kg^{-1} to 1588 ± 162 Bq.kg^{-1} with an average 792 Bq.kg^{-1}, respectively. The radon exhalation rate and radon concentration in the soil of study area varies from 2.20 × 10^{-5} Bq.kg^{-1}h^{-1} to 3.2 × 10^{-5} Bq.kg^{-1}h^{-1} and 287 Bq/m^3 to 417 Bq/m^3, respectively. It was observed that the distribution of natural radionuclide in the soil of study area is not uniform and concentrated along geological active region. These values of radionuclide and radon mass exhalation rate may be used as baseline data for further study in the area.

1. Introduction

Natural radionuclide is most significant parameter to assess the effect of external and internal exposure in outdoor and indoor Environment. These radionuclides are heavily unstable element so they converted into another atom after spontaneously releasing alpha, beta and gamma decay. Gamma ray can penetrate deeply into material so that gamma ray emitters are hazardous for either external or internal irradiation. The degree of hazard for a given radiation depends on the natural radionuclides present in that area.

Natural radionuclide distribution is directly responsible for radon, thorn and progeny levels in the surrounding dwellings. When radium atom decays in soil grains, its daughter product, radon, enters in air filled pore space between the grains. This is known as emanation process and the total amount of radon emitted by pore space to environment is called the exhalation. The fraction of radon emanation and its exhalation rate depend on the geology of the area, soil porosity, structures (shears, faults and thrusts) and associated uranium mineralization (Choubey & Ramola, 1997; Duenas & Fernandez, 1987; Holkko & Liukkonen, 1993; Hubbard & Hagberg, 1996; Hubbard, Hagberg, & Enflo, 1992; Markkanen & Arvela, 1992;

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Prasad, Prasad, Gusain, Choubey, & Ramola, 2008; Ramola & Choubey, 2003; Ramola et al., 2012; Ramola, Singh, & Virk, 1988). Radon emanation rate is highest when soil moisture is between 15 and 20% in weight (Damkjaer & Korsbeck, 1985; Lindmark & Rosen, 1985; Stranden, Kolstad, & Lind, 1984). Several studies were conduct throughout the world in indoor radon because researcher found that breathing radon in indoor air can cause lung cancer (Harley, 2008; ICRP, 1993; Samat, 1989; UNSCEAR, 1993). The aim of present work is to study the distribution of natural radionuclides along main central thrust of Garhwal Himalaya, India. The level of radionuclide contents depends on the geological formation, micro-cracks and defects in rocks. This investigation is important to generate geological controlled baseline data of radionuclides in Himalayan region. These radionuclides may be used to estimate and assess the terrestrial radiation dose to the human population and to identify areas of high natural radiation hazard.

2. Geology of area

The study Area is located along Main Central Thrust (MCT) Area. This area was affected by large number of natural disasters such as landslide, earthquake, rock falls etc. The main cause of earthquake in this region is due to the movement of the Indian plate towards the Eurasian plate at the rate of about 50 mm/Year (Bilham, 2004; Kumar et al., 2007; Sridevi, 2004). Large number of new tectonic activities per year is one of the unique properties of this area. These activities developed large number of fault, weak plans and change the geological parameter. Rocks characterized in this area are Quartzite, phyllite, metabasic, and granite etc. Soil samples collected from the area are fine and coarse with red, black and dark colors. Dark color soil usually indicates high organic content. The soil temperature and relative humidity in this area at the time of soil collection lies between 20 °C to 40 °C and 62% to 80%. This area has major risk for human life including the large number of new tectonic activities.

3. Experimental techniques

3.1. Radionuclide analysis

3.1.1. Sample collection and preparation

The soil samples were collected from different location in study area. Samples were taken from a depth of 25–35 cm after removing the possible contamination on the top surface of undisturbed soil (IAEA, 2003). After the collection, the organic material pebbles, roots and vegetation were separated from the soil sample and all samples were cursed into a fine powder. The samples were then dried in electric furnace at 110 °C for one day and a fine quality of the sample powder was obtained using a sieve of 150 micron size mesh. The dried samples of weight 500 gm were packed in air tight Merinelli beakers for about one month in order to allow the secular equilibrium between ^{226}Ra, ^{222}Rn and their short lived decay products.

3.1.2. Gamma rays spectrometer technique

The prepared soil samples were placed in the protection unit of gamma rays spectrometry for the counting time of three hours. The estimation of natural nuclides in soil sample were carried out using scintillation NaI(Tl) gamma radiation detectors of size 63 mm × 63 mm with a multiple channel analyzer.

3.1.3. Energy calibration

The energy calibration was done at 661 keV of ^{137}Cs point source available from Atomtex, Belarus with the gamma ray spectrometer. The calibrated energy peak identify 1460 keV for ^{40}K, the activity of ^{226}Ra from 1764 keV analysis was performed gamma line of ^{214}Bi and that of ^{232}Th from 2620 keV gamma line of ^{208}Tl. The activity concentration of these soil samples were calculated from intensity of each line, taking into account the mass as well as geometry of the sample. After the calibration the detector was standardized by uranium, thorium and potassium standard sources. Because some radioactivity is present everywhere (background radiation), the spectrum was analyzed without the presence of source. The background radiation was subtracted from the recorded value. Lead absorbers were also placed around the apparatus to reduce background radiation.

3.1.4. Radium equivalent activity

The radionuclide concentration, defined in terms of radium equivalent activity (Ra_{eq}) in Bq.kg^{-1} is a single quantity to introduce the radiation hazard associated with ^{226}Ra, ^{232}Th and ^{40}K. The radium equivalent activity is calculated by the following formula (Ramola et al., 2008; UNSCEAR, 2000):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_k$$

where A_{Ra}, A_{Th} and A_K are activity concentrations (Bq.kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in the soil sample.

3.2. Assessment of radiological hazards

3.2.1. Health effect

The external and internal health effects due to presence of radionuclide are given by the formula:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

where A_K, A_{Th} and A_{Ra} are the Activity concentration (Bq.kg^{-1}) of ^{40}K, ^{232}Th and ^{226}Ra, respectively, in the soil samples.

3.2.2. Absorbed dose

The absorbed dose rate due to natural radionuclide was calculated using the conversion factor (UNSCEAR, 2000):

$$D = 0.0417A_K + 0.604A_{Th} + 0.462A_U$$

where A_K, A_{Th}, and A_U are the average activity concentrations (Bq.kg^{-1}) of ^{40}K, ^{232}Th and ^{226}Ra, respectively, in the soil samples. About 98% of the external gamma dose rate from ^{238}U series is delivered by the ^{226}Ra sub-series, so disequilibrium, if any, between ^{226}Ra and ^{238}U will not affect the dose

estimation from the measurement of ^{226}Ra (Shanbhag, Sartandel, Ramachandran, & Puranik, 2005).

3.2.3. *Annual effective dose*

The annual effective dose resulting from the absorbed dose is also obtained using following formula (UNSCEAR, 2000):

$$\text{Indoor(mSv)} = (\text{Absorbed dose})\text{nGy/h} \times 8760 \times 0.8 \times 0.7\ \text{Sv/Gy} \times 10^{-6}$$

$$\text{Outdoor(mSv)} = (\text{Absorded dose})\ \text{nGy/h} \times 8760 \times 0.2 \times 0.7\text{Sv/Gy} \times 10^{-6}$$

3.3. *Radon mass exhalation rate from soil*

The radon exhalation rate was measured by the "Seal can technique". The dried sample with 150 micro mesh sized and 500 gm mass was kept in a cylindrical can of 30 cm height and 12 cm diameter with LR-115 plastic tracked detector, fixed inside the can and kept undisturbed for one month. After an exposure period of one month, LR-115 films were retrieved, chemically etched in 2.5 N NaOH solution in an etching bath at temperature of 60 °C for a period of 90 min for developing the tracks recorded and registered in the films. The detectors were washed in double distilled water and the resulting track density was counted with a spark counter. The radon exhalation rate was measured by the relation (Fleischer & Mogro-Campero, 1978; Khan, Prasad, & Tyagi, 1992):

$$E_x = \frac{CV\lambda}{M\left[T + \frac{1}{\lambda}\{e^{-\lambda t} - 1\}\right]}$$

where, E_x is radon exhalation rate (Bq.m^{-2} h^{-1}), C is measured radon concentration (Bq.m^{-3} h), V is the effective volume of Can (m^3), λ is the decay constant for radon (h^{-1}), T is the exposure time (h) and M is the mass of the soil samples.

3.4. *Radon concentration*

Radon concentration in soil sample is calculated using the formula

$$C_{Rn}(\text{Bq/m}^3) = \frac{T_{Rn}}{K_{Rn} \times t}$$

where T_{Rn} is the radon track density (track/cm^2), K_{Rn} is the calibration factor for radon (0.02 track.cm^{-2}d^{-1}/Bq.m^{-3}) as measured by Eappen and Mayya (2004) and t is the exposure time.

4. Results and discussions

The data presented in Table 1 show the activity concentrations of natural radionuclides along Main Central thrust (MCT) in Garhwal Himalaya. The activity concentrations of natural radionuclides, ^{226}Ra, ^{232}Th and ^{40}K, in MCT area varies from 8 ± 1 Bq.kg^{-1} to 285 ± 28 Bq.kg^{-1} with an average of 64 Bq.kg^{-1}, 7 ± 1 Bq.kg^{-1} to 136 ± 15 Bq.kg^{-1} with an average 69 Bq.kg^{-1} and 115 ± 18 Bq.kg^{-1} to1588±162 Bq.kg^{-1} with an average 792 Bq.kg^{-1}, respectively. The study area comprises four major section along MCT; Uttarkashi, Budhakedar, Ukhimath and Helang areas. The measured activity of ^{226}Ra in soil samples collected from Uttarkashi, Budhakedar, Ukhimath and Helang areas varies from 45 ± 7 Bq.kg^{-1} to 285 ± 29 Bq.kg^{-1} with an average of 99 Bq.kg^{-1}, 66 ± 7 Bq.kg^{-1} to 165 ± 18 Bq.kg^{-1}, with an average of 94 Bq.kg^{-1}, 8 ± 7 Bq.kg^{-1} to 50 ± 18 Bq.kg^{-1} with an average of 23 Bq.kg^{-1} and 26 ± 7 Bq.kg^{-1} to 57 ± 18 Bq.kg^{-1} with an average of 46 Bq.kg^{-1}, respectively. The measured activity of ^{232}Th in soil samples collected from Uttarkashi, Budhakedar, Ukhimath and Helang areas varies from 42 ± 6 Bq.kg^{-1} to 95 ± 11 Bq.kg^{-1} with an average of 69 Bq.kg^{-1}, 12 ± 5 Bq.kg^{-1} to 136 ± 15 Bq.kg^{-1} with an average of 44 Bq.kg^{-1}, 7 ± 1 Bq.kg^{-1} to 88 ± 16 Bq.kg^{-1} with an average of 30 Bq.kg^{-1} and 11 Bq.kg^{-1} to 35 ± 6 Bq.kg^{-1} with an average of 20 Bq.kg^{-1}, respectively. The ^{40}K contents in the collected soil samples from Uttarkashi, Budhakedar, Ukhimath and Helang areas were found to vary from 348 ± 89 to 1048 ± 162 Bq.kg^{-1} with an average of 711 Bq.kg^{-1}, 553 ± 106 to 1588 ± 185 Bq.kg^{-1} with an average of 1169 Bq.kg^{-1}, 115 ± 18 to 885 ± 135 Bq.kg^{-1} with an average of 349 Bq.kg^{-1}, and 350 ± 120 Bq.kg^{-1} to 1405±169 Bq.kg^{-1} with an average of 883 Bq.kg^{-1}, respectively.

The measured values of activity concentrations were comparable to recommended values of background gamma radiation report by UNSCEAR (2000). It was found that Ukimath and Helang have low activity level compared to Uttarkshi and Budhakedar. The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are higher than recommended value in Budhakedar and Uttarkshi. Some locations in Uttarkashi and Budhakedar (UK02, UK04, UK05, UK10, UK13 and BK01, BK03, BK04, BK13) areas show high values of radium activity. The high value of radium content in this area may be due to combined effects of uranium mineralization and the presence of nearby thrust plane (Choubey, Bist, Saini, & Ramola, 1999; Ramola et al., 1988).

Consequently, there is elevated radon concentration in soils and weathered bedrock where they are located (Otton, 1989; Ramola, Choubey, Prasad, Prasad, & Bartarya, 2006). Simultaneously high concentrations of ^{232}Th were observed in some soil samples (UK02, UK05, UK07, UK09, UK10, UK13, UK14, BK03, BK04, UM01, UM02 and UM09) due to presence of monazite in local soil (Mohanty, Sengupta, Das, Vijayan, & Saha, 2004).

Natural radionuclide and the associated external exposure due to gamma radiation depends primarily on the geological and geographical condition and exist at different levels in the soil of each region of the world (Chowdhury, Kamal, Alam, Yeasmin, & Mostafa, 2006; Gusain et al., 2009; Merdanoglu & Altinsoy, 2006; Rautela et al., 2012). Since the distribution of radionuclides is not uniform, the exposure due to the radionuclides is estimated in terms of radium equivalent radioactivity. The quantity of radium equivalent activity is also found high than the recommend value 370 Bq.kg^{-1} (OECD, 1979) in Uttarkshi and Budhakether areas. The absorbed dose rates due to the presence of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of Uttarkashi and Budhakedar areas were found much higher than the world average value 44 nGy/y (UNSCEAR, 1982). The indoor and outdoor annual effective dose rates in Uttarkashi and Budhakether area are higher than recommend value of 0.46 mSv yr^{-1} (Bennett, 1997; UNSCEAR, 1993). The average value for external and internal health hazard indices (H_{ex} and

Table 1 – Levels of radionuclides and calculated doses in collected soil samples from the MCT area of Garhwal Himalaya.

Sample code	^{226}Ra (Bq.kg^{-1})	^{232}Th (Bq.kg^{-1})	^{40}K (Bq.kg^{-1})	Radium equivalent Activity (Bq.kg^{-1})	Absorbed dose (nGyh^{-1})	Annul effective dose (mSv)		Health effect	
						Indoor	Outdoor	H_{ex}	H_{in}
UK01	45 ± 7	42 ± 6	798 ± 123	167	79	0.39	0.10	0.57	0.45
UK02	134 ± 15	95 ± 11	1048 + 162	351	163	0.80	0.20	1.31	0.95
UK03	57 ± 8	44 ± 6	678 ± 114	172	81	0.40	0.10	0.62	0.46
UK04	101 ± 12	57 ± 8	1047 ± 151	263	125	0.61	0.15	0.98	0.71
UK05	121 ± 13	89 ± 10	348 ± 89	275	124	0.61	0.15	1.07	0.74
UK06	71 ± 9	49 ± 7	1041 ± 147	221	106	0.52	0.13	0.79	0.60
UK07	90 ± 11	83 ± 10	738 ± 125	266	122	0.60	0.15	0.96	0.72
UK08	66 ± 8	54 ± 7	871 ± 131	210	99	0.49	0.12	0.75	0.57
UK09	63 ± 8	79 ± 9	616 ± 114	223	103	0.50	0.13	0.77	0.60
UK10	285 ± 29	93 ± 11	NA	418	188	0.92	0.23	1.90	1.13
UK11	89 ± 11	73 ± 9	826 ± 132	257	120	0.59	0.15	0.93	0.69
UK12	65 ± 8	66 ± 8	617 ± 113	207	96	0.47	0.12	0.73	0.56
UK13	129 ± 15	83 ± 11	576 ± 138	292	134	0.66	0.16	1.14	0.79
UK14	78 ± 9	63 ± 8	758 ± 123	226	106	0.52	0.13	0.82	0.61
BK01	103 ± 12	66 ± 8	836 ± 134	262	122	0.60	0.15	0.99	0.71
BK02	69 ± 9	58 ± 7	553 ± 106	195	90	0.44	0.11	0.71	0.53
BK03	165 ± 18	109 ± 13	1025 ± 158	400	185	0.91	0.23	1.53	1.08
BK04	114 ± 14	136 ± 15	1049 ± 165	389	179	0.88	0.22	1.36	1.05
BK05	66 ± 7	22 ± 3	1092 ± 127	182	89	0.44	0.11	0.67	0.49
BK06	84 ± 10	25 ± 5	1373 ± 163	225	111	0.55	0.14	0.84	0.61
BK07	85 ± 10	19 ± 5	1588 ± 185	234	117	0.57	0.14	0.86	0.63
BK08	85 ± 10	20 ± 5	1398 ± 165	221	110	0.54	0.13	0.83	0.60
BK09	73 ± 9	22 ± 4	1252 ± 148	201	99	0.49	0.12	0.74	0.54
BK10	73 ± 9	18 ± 4	1292 ± 152	198	98	0.48	0.12	0.73	0.54
BK11	77 ± 9	23 ± 5	1223 ± 146	204	100	0.49	0.12	0.76	0.55
BK12	89 ± 10	17 ± 4	1378 ± 164	219	109	0.53	0.13	0.83	0.59
BK13	107 ± 12	12 ± 5	1304 ± 160	225	111	0.54	0.14	0.90	0.61
BK14	89 ± 11	18 ± 4	1212 ± 147	208	103	0.50	0.13	0.80	0.56
UM01	41 ± 10	88 ± 16	629 ± 113	215	98	0.48	0.12	0.69	0.58
UM02	17 ± 2	18 ± 2	280 ± 33	64	30	0.15	0.04	0.22	0.17
UM03	19 ± 2	18 ± 2	290 ± 34	67	32	0.16	0.04	0.23	0.18
UM04	46 ± 1	23 ± 6	145 ± 12	90	41	0.20	0.05	0.37	0.24
UM05	25 ± 2	16 ± 2	343 ± 39	74	36	0.17	0.04	0.27	0.20
UM06	25 ± 2	28 ± 3	403 ± 45	96	45	0.22	0.06	0.33	0.26
UM07	13 ± 1	11 ± 1	202 ± 25	44	21	0.10	0.03	0.15	0.12
UM08	8 ± 1	10 ± 1	148 ± 21	34	16	0.08	0.02	0.11	0.09
UM09	50 ± 10	87 ± 17	885 ± 132	243	113	0.55	0.14	0.79	0.66
UM10	18 ± 2	18 ± 2	291 ± 34	66	31	0.15	0.04	0.23	0.18
UM11	21 ± 2	26 ± 3	399 ± 42	89	42	0.21	0.05	0.30	0.24
UM12	17 ± 2	16 ± 1	265 ± 31	60	29	0.14	0.04	0.21	0.16
UM13	15 ± 1	12 ± 1	193 ± 25	47	22	0.11	0.03	0.17	0.13
UM14	8 ± 1	7 ± 1	115 ± 18	27	13	0.06	0.02	0.09	0.07
HE01	57 ± 8	35 ± 6	384 ± 91	137	63	0.31	0.08	0.52	0.37
HE02	41 ± 6	33 ± 5	801 ± 104	150	72	0.35	0.09	0.52	0.40
HE03	57 ± 8	29 ± 5	1405 ± 169	207	102	0.50	0.13	0.71	0.56
HE04	34 ± 5	20 ± 3	966 ± 117	137	68	0.33	0.08	0.46	0.37
HE05	52 ± 6	22 ± 3	976 ± 114	159	78	0.38	0.10	0.57	0.43
HE06	47 ± 6	17 ± 3	985 ± 114	147	73	0.36	0.09	0.52	0.40
HE07	26 ± 7	15 ± 7	350 ± 120	74	36	0.17	0.04	0.27	0.20
HE08	50 ± 6	18 ± 3	1043 ± 122	157	78	0.38	0.10	0.56	0.42
HE09	53 ± 6	18 ± 8	851 ± 102	144	71	0.35	0.09	0.53	0.39
HE10	44 ± 5	20 ± 20	912 ± 107	143	70	0.35	0.09	0.50	0.39
HE11	51 ± 6	18 ± 3	1081 ± 119	155	77	0.38	0.09	0.56	0.42
HE12	44 ± 5	11 ± 3	839 ± 97	124	62	0.30	0.08	0.45	0.34
HE13	39 ± 5	15 ± 3	859 ± 101	127	63	0.31	0.08	0.45	0.34
HE14	28 ± 5	18 ± 3	985 ± 115	130	65	0.32	0.08	0.43	0.35

H_{in}) due to presence of natural radionuclide in the soil samples are less than unity in Helang and Ukimath area, which is highly acceptable and within safe limit in the study area (UNSCEAR, 1993; 2000). However, the health indices at some location of Uttarkshi and Budhakether were found above unity.

A strong correlation ($R^2 = 0.80$) was found between ^{226}Ra and Ra_{eq} activity in soil samples of study area. A solid linear

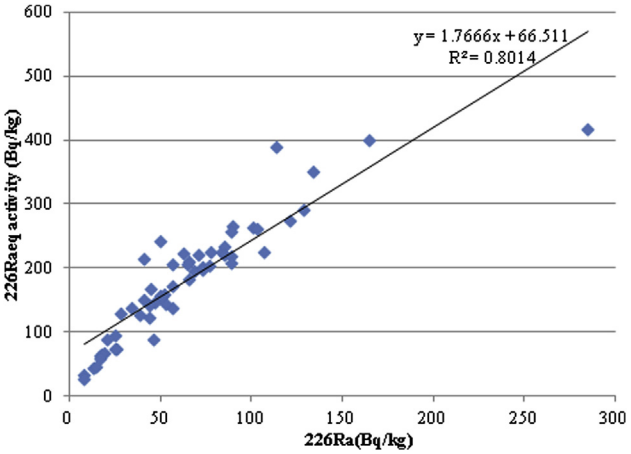

Fig. 1 – Correlation between ^{226}Ra and $^{226}Ra_{eq}$.

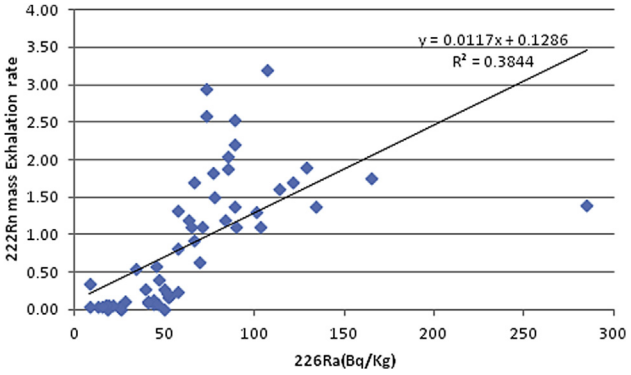

Fig. 2 – Correlation between ^{226}Ra and ^{222}Rn mass exhalation rate.

line in Fig. 1 shows that high amount of ^{226}Ra and its decay products is directly responsible to the exposure of high background radiation in the area. The gamma radiation dose rate in the study was found positively correlated with activity concentrations present in the soil. The value of natural radionuclides was found positively correlated with absorbed dose rate, annual effective dose and health effect.

The measuredvalues of radon mass exhalation rate and radon concentrations are shown in Table 2. The radon exhalation rate and radon concentration in soil of study area were found high at some locations of Uttarkshi and Budhakether areas. The radon exhalation rate and radon concentration in the soil of study area varies from 2.20×10^{-5} $Bq.kg^{-1}h^{-1}$ to 3.2×10^{-5} $Bq.kg^{-1}h^{-1}$ and 287 Bq/m^3 to 417 Bq/m^3, respectively. A positive correlation ($R^2 = 0.38$) was found between radon mass exhalation rate and radium activity (Fig. 2). The radon concentration was recorded high close to the Main Central Thrust, which is considered as a geologically active thrust plan.

5. Conclusion

It is concluded that the distribution of natural radionuclide in the soil of study area is not uniform and concentrated along

Table 2 – Measured values of radon concentration and radon exhalation rate in soil samples.

Sample code	Radon concentration (Bq/m^3)	Radon Mass exhalation rate ($Bq.kg^{-1}h^{-1}$)	Sample code	Radon concentration (Bq/m^3)	Radon Mass exhalation rate ($Bq.kg^{-1}h^{-1}$)
UK01	78	0.59×10^{-5}	BK14	330	2.54×10^{-5}
UK02	180	1.38×10^{-5}	UM01	13	0.10×10^{-5}
UK03	171	1.32×10^{-5}	UM02	7	0.05×10^{-5}
UK04	182	1.30×10^{-5}	UM03	7	0.05×10^{-5}
UK05	217	1.70×10^{-5}	UM04	9	0.07×10^{-5}
UK06	148	1.10×10^{-5}	UM05	5	0.04×10^{-5}
UK07	155	1.10×10^{-5}	UM06	3	0.02×10^{-5}
UK08	121	0.92×10^{-5}	UM07	5	0.04×10^{-5}
UK09	166	1.20×10^{-5}	UM08	6	0.04×10^{-5}
UK10	183	1.40×10^{-5}	UM09	0	0.00×10^{-5}
UK11	287	2.20×10^{-5}	UM10	2	0.01×10^{-5}
UK12	154	1.10×10^{-5}	UM11	8	0.06×10^{-5}
UK13	257	1.90×10^{-5}	UM12	8	0.06×10^{-5}
UK14	237	1.50×10^{-5}	UM13	5	0.04×10^{-5}
BK01	152	1.10×10^{-5}	UM14	46	0.35×10^{-5}
BK02	84	0.64×10^{-5}	HE01	108	0.82×10^{-5}
BK03	229	1.76×10^{-5}	HE02	14	0.11×10^{-5}
BK04	211	1.62×10^{-5}	HE03	32	0.24×10^{-5}
BK05	222	1.70×10^{-5}	HE04	72	0.55×10^{-5}
BK06	167	1.20×10^{-5}	HE05	22	0.17×10^{-5}
BK07	246	1.89×10^{-5}	HE06	53	0.40×10^{-5}
BK08	268	2.05×10^{-5}	HE09	26	0.19×10^{-5}
BK09	336	2.58×10^{-5}	HE10	18	0.13×10^{-5}
BK10	383	2.94×10^{-5}	HE11	29	0.22×10^{-5}
BK11	237	1.82×10^{-5}	HE12	10	0.08×10^{-5}
BK12	179	1.37×10^{-5}	HE13	36	0.27×10^{-5}
BK13	417	3.20×10^{-5}	HE14	16	0.12×10^{-5}

geological active area. The radionuclide distribution is main contributor to the radiation exposure and assessment of background radiation in the study area. A weak positive correlation was found between radium content and radon mass exhalation rate in the soil samples collected from the area. These values of radionuclide and radon mass exhalation rate are useful to generate baseline data for natural neo-tectonic activities in future.

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